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HIGH TEMPERATURE THERMOCOUPLE INSTALLATION METHODS FOR HYPERSONIC VEHICLES

John Feie and Larry Kretz

**Advanced Structural Concepts Branch
Structures Division**

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Interim Report**

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14. ABSTRACT This presentation discusses the joint effort between the Air Force Research Laboratory (AFRL) and NASA Langley Research Center to establish a process for bonding type C and type K thermocouples to high temperature materials. Bonded samples of both type C and type K thermocouples will be tested in a combined thermal-vibration environment. A baseline and alternate installation method will be tested. The instrumented specimens will be mounted on a shaker and heated with quartz lamps. The specimens will be exposed to three different environments: a launch vibration spectrum, a re-entry vibration spectrum, and a high temperature degradation environment. The installation methods that are capable of withstanding these three environments will be considered for use in hypersonic flight testing.					
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High Temperature Thermocouple Installation Methods for Hypersonic Vehicles

American Institute of Aeronautics and Astronautics (AIAA) Dayton-
Cincinnati Aerospace Sciences Symposium

4 March, 2008

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Introduction



- **Hypersonic Vehicle History and Background**
- **Air Force Performance Goals**
- **Hypersonic Vehicle Thermocouple Instrumentation History and Limitations**
- **Recent Thermocouple R & D at the AFRL**
- **Verification and Testing of TC Installation Methods**
- **Results and Conclusions**



Hypersonic Vehicle Thermal Structures Test Challenges



- **Air Force Requirements for Hypersonic Vehicles**
 - Space Access
 - Hypersonic Cruise
- **High Speed = Extreme Environment**
 - Acoustics
 - Heating
 - Flight Loads
- **Extreme Environment = Advanced Materials & Structures**





Hypersonic Vehicle Thermal Structures Test Challenges



Performance Goals

- Rapid turn 48 hrs
- 3X lower ops cost
- Vehicle reliability 0.995
- All Wx availability 90%
- 250 Sortie Airframe
- 100 Sortie Propulsion & Systems



BASELINE
EELV, Shuttle,
Aircraft Ops



Near Term (09)

- Rapid turn 24 hrs
- 10X lower ops cost
- Vehicle reliability 0.999
- All Wx availability 95%
- 500 Sortie Airframe
- 250 Sortie Propulsion & Systems



Mid Term (15)

- Rapid turn 4 hrs
- 100X lower ops cost
- Vehicle reliability 0.9998
- All Wx availability 98%
- 1,000 Sortie Airframe
- 500 Sortie Propulsion & Systems



Far Term (25)

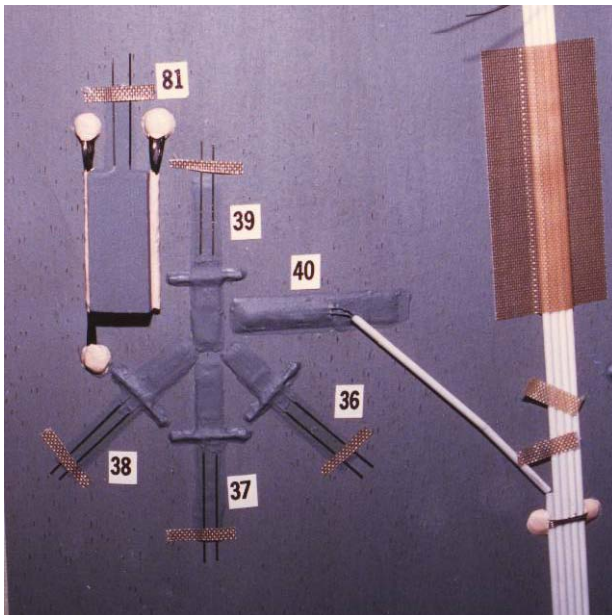


Hypersonic Vehicle Thermal Structures Test Challenges



Instrumentation Difficulties

- Temperature Capability
- Attachment Methods
- Specimen Compatibility
- Compatibility with Loading Systems



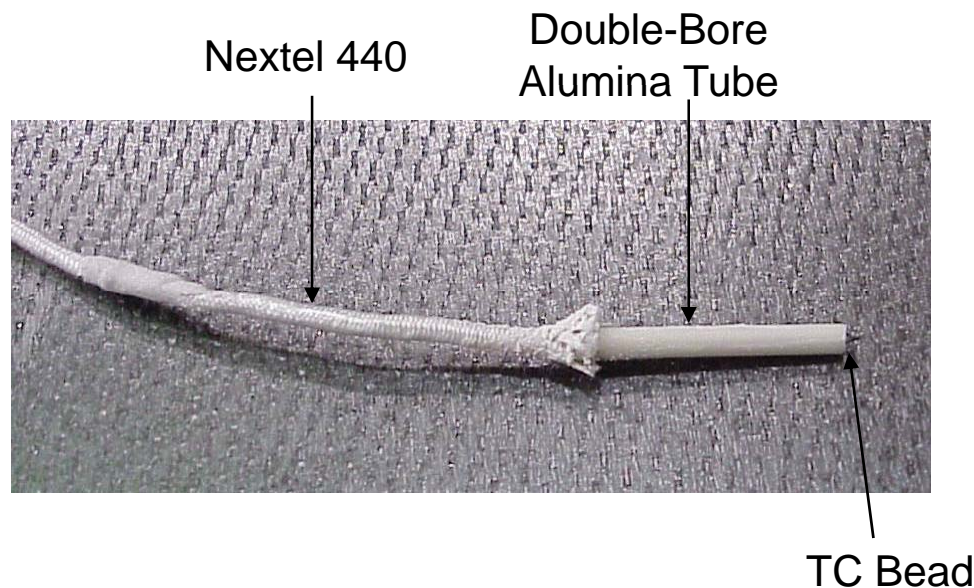
- Instrumentation did not adhere
- Sheath/Lamp arcing
- Emissivity change
- Coating damage



Carbon-Carbon Thermocouple Surface Installation



- Surface TC's mounted through-the-thickness of aeroshell
- Type C, Nextel 440 insulation
- TC is potted at surface with ceramic cement
- Thermocouple mounting procedure successfully developed and tested to $>3000^{\circ}\text{F}$ in a 1 inch thick C-C specimen at AFRL



TC potted slightly below C-C Surface
(to be covered with graphite)



Surface TC also potted at backface

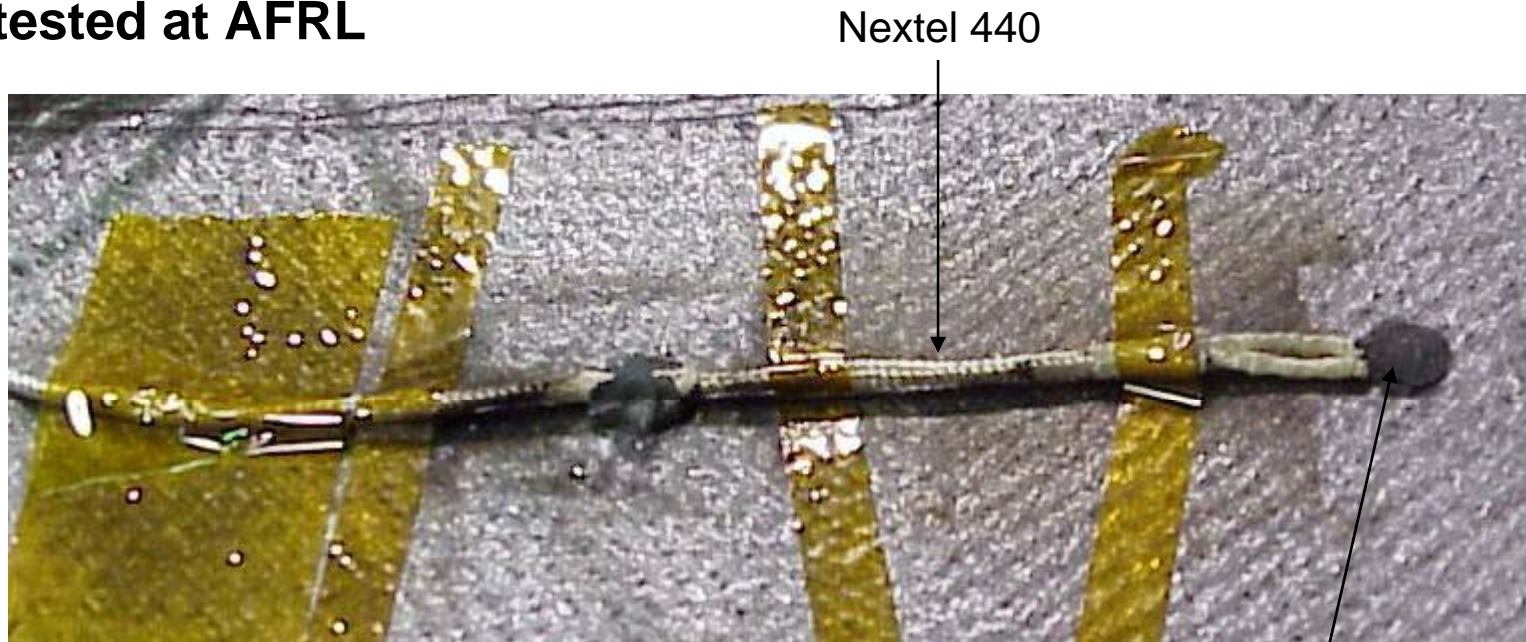




Carbon-Carbon Thermocouple Surface Installation



- Backface TC's mounted to aeroshell surface
- Type K, Nextel 312 insulation
- Thermocouples mounted using graphite cement
- Thermocouple mounting procedure successfully developed and tested at AFRL



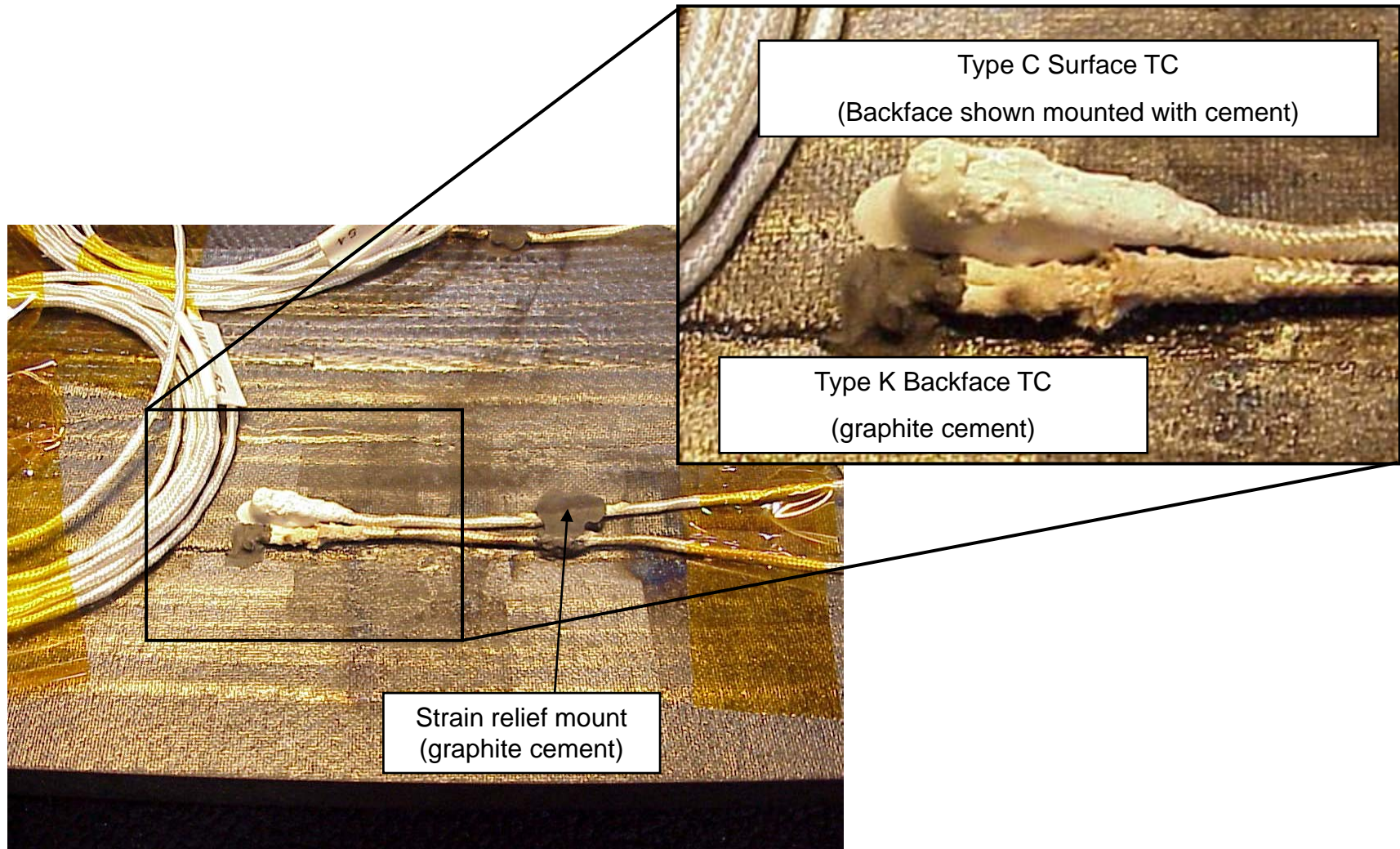
Nextel 440

Kapton Tape (used for assembly only)

TC Bead (w/ graphite cement)



Thermocouple Mounting

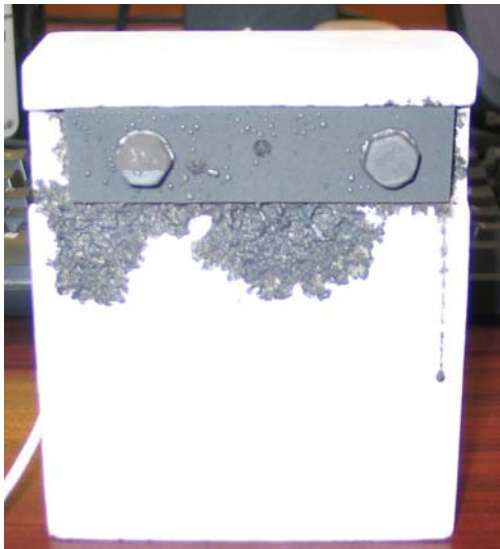




Verification of TC Installation Methods



- Quartz lamp heaters used to simulate thermal environment ($> 2000^{\circ}\text{F}$)
- Specimen mounted to shaker to simulate vibration environment ($> 15\text{ g's}$)
- Insulation needed to keep shaker head near room temperature
- 3" and 8" coupons tested
- Thermocouples imbedded into coupon and backfilled with graphite cement



- Coated specimens failed, due to melting of coating
- Melted, corrosive coating attacked the insulation requiring the test to be aborted





Thermal Vibration Testing





Results and Conclusions



- **Hypersonic vehicle flight involves extreme thermal and vibration loads**
- **Extreme environment and advanced materials require development of new methods for instrumentation installation**
- **High temperature cements offer potential solution**